2 Why space?

The United States must pursue space as a commercial enterprise – in addition to civil and military operations – because space might be the largest remaining frontier for economic growth, national security, and scientific discovery. Opening such a frontier has profound social and technological implications to all citizens; establishing a more robust presence in space and harnessing its resources will increasingly contribute to key national imperatives. As the new century unfolds, the key barrier to fulfilling the promise of the space frontier is transportation to and from Earth's surface – breaking from the Earth's gravity. Some of the more fundamental issues relating to increased space utilization and related transportation needs are addressed throughout this report.

- How does space access affect every United States citizen?
- How does space meet national imperatives?
- What enables space transportation systems?
- How can we realize a robust space enterprise?

View of Earth from the Space Shuttle

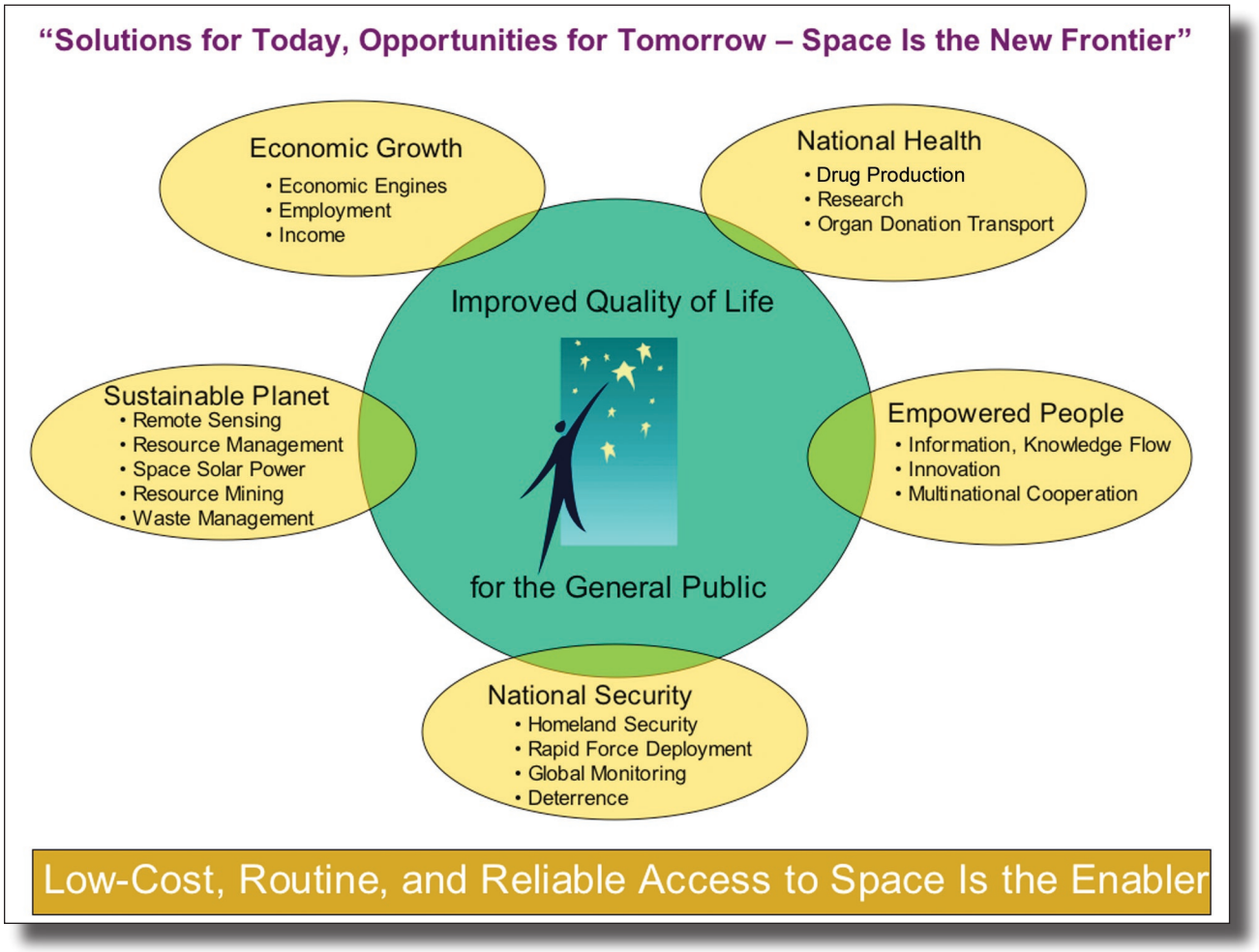


Figure 5. National imperative

2.1 How does space access affect every United States citizen?

Space access can contribute to key national imperatives that broadly affect every U.S. citizen.

While space provides new exploration frontiers for the human spirit, space access provides more substantial opportunities to grow the nation as a whole with commerce, technology, aerospace leadership, and new economic opportunities for every citizen. Such profound outcomes can help the United States realize national imperatives for economic growth, national health, empowered people and businesses, a sustainable planet, and national security to ultimately improve quality of life (see Figure 5). This national imperative is enabled by low-cost, routine, and reliable access to space, which is a key feature of a national space enterprise. Low-cost space access will provide the fertile ground to grow economies that will nourish the nation and sustain a future leadership in world commerce.

Examining the outcomes in closer detail shows how each element contributes to the overall improved quality of life for every citizen.

International Space Station

National Health

National health benefits are realized through a robust space industry by advancing medical research in the microgravity environment. Purer medicines have already been created in the unique gravity-free space environments. When there is a flourishing space enterprise, national health can be improved through many types of services. For example, if a patient on the U.S. East Coast needs a heart transplant and the only matched donor organ is in Asia, it can be transported in hours rather than days through a global suborbital transportation market.

Empowered People and Businesses

Space provides the capability to get everyday information (e.g., instant news, Social Security benefits, TV shows, bank statements, and real-time stock updates) to the individual anytime and anywhere. A robust space industry empowers the individual through rapid travel and the exchange of information and goods. Systems in space enable rapid flow of immense information, which provides knowledge by delivering the information across the planet, ultimately breaking through boundaries and bringing us closer together.

Navstar Global Positioning System (GPS) satellite[2]

[2] A.R. Curtis, "The Satellite Wars," *Space Today Online*, n.d., <http://www.spacetoday.org/Satellites/YugoWarSats.html> (September 4, 2003).

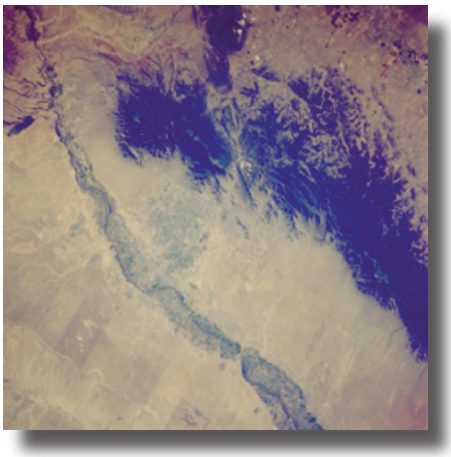
The Astronaut Hall of Fame located at the KSC Visitor Complex

Economic Growth

When approached in the light of how it impacts our individual daily lives, space can provide national and personal wealth through economic growth. As an economic engine, space powers new services, new products, and new industries – which creates jobs. When the space enterprise flourishes, communities can recruit more businesses and create new employment opportunities for their citizenry. Indirect industries, as well as direct space industries, benefit from the space economy. For every dollar spent on direct space business, the local economy receives business through indirect services in much the same way that seaports enhance their local economies.

Sustainable Planet

There exists a delicate balance between Earth's resource availability and its resource usage. A growing world population demands more resources, so careful resource management is critical. Space provides an environment to more efficiently and effectively manage existing resources. For example, food production and air and water management can be enhanced through satellite monitoring. If remote sensing capabilities developed in support of the space program can predict water availability from the Colorado mountain snowfall and thereby help New Mexico better manage its water usage, the space program will have proven its worth to a single farmer and an entire state. And this same enhanced management can be applied to all the states in the region. Space also provides the opportunity for exploiting new resources. Harnessing space solar power and mining resources from other planetary bodies (e.g., hydrogen 3 on the moon) can augment the Earth-based resource pool.



Albuquerque, New Mexico, U.S.A. June 1991[3]

U.S. Air Force rapid troop deployment vehicle

National Security

National security enables the freedom we all enjoy today. The military depends on the ability to understand and rapidly respond to "trouble spots" globally. Today, space has become an integral component of U.S. military planning. A sure sign of its essential nature can be found in the dozens of satellites from the United States that supported military campaigns in the Republic of Iraq in 2003, the Islamic State of Afghanistan in 2001, and the Federal Republic of Yugoslavia in 1999. In the future, space can provide an environment for enhanced global monitoring and an operationally responsive military with rapid global force deployment and deterrence capabilities. Homeland security is enhanced by this space-based capability.

[3] NASA Johnson Space Center, Earth Sciences and Image Analysis, Earth from Space: STS040-614-061 Albuquerque, New Mexico, USA, June 1991, <http://earth.jsc.nasa.gov/sseop/efs/credits.htm> (May 8, 2003).

2.2 How does space meet the national imperative?

By developing, operating, and growing a robust space enterprise.

A space enterprise contains markets (customers and products), a space transportation enterprise, and investment mechanisms as reflected in Figure 6.

The **space market** consists of customer sectors and product groups. Customers are segmented into three traditional customer sectors: civil, military, and commercial.

- **Civil space customers** (science and exploration) focus on the scientific quest to understand the Earth, life, and the solar system. The civil space market focuses on increasing our knowledge about the nature of life. For example, NASA's mission is "to understand and protect our home planet; to explore the universe and search for life; to inspire the next generation of explorers…as only NASA can." To accomplish this mission, access to space must be affordable. NASA is looking for operational efficiencies such as improvements in turnaround time and ground processing, launch costs reductions, improved safety, and reduced risk to its astronauts, critical hardware and infrastructure, and workforce.

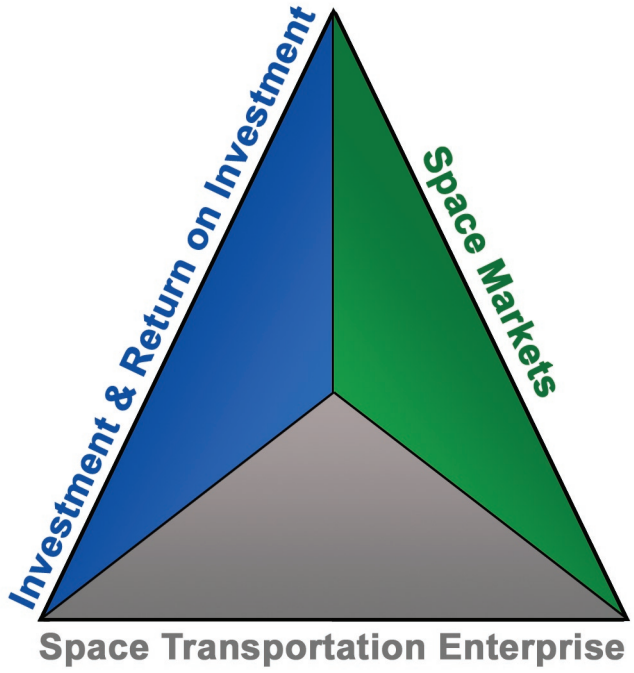


Figure 6. Space enterprise

- **Military space customers** focus on providing national security. From a military perspective, rapid-response space access is important to U.S. national security and economic well-being. The Department of Defense needs responsive space transportation for operations such as pop-up reconnaissance and rapid global surveillance to monitor, control, or react to evolving crises or targets of interest. This need requires the ability to deploy assets to a "hot spot" in a matter of hours rather than days.

- **Commercial space customers** focus on providing products and services as a business enterprise. Today the commercial space sector provides medical research benefits, convenience, and entertainment. Whereas these markets are limited today because of cost-prohibitive space access systems, tomorrow's consumer opportunities are boundless. Paralleling the commercial aviation sector, multitudes of opportunities are enabled through low-cost, reliable space transportation.

Some products and services provided by the space market, including global real-time monitoring, global communication, and cost-effective, reliable space transportation, span all customer sectors. However, today's market for space is primarily civil- and military-driven. Civil market examples include global, real-time monitoring (remote sensing) for weather and world population studies. Space transportation provides the means to deliver science satellites and astronauts into space to complete science-related missions. The military customer is provided with global reconnaissance monitoring through satellite delivery. Global communication provides the military with worldwide troop communication. Global, real-time monitoring also supports the commercial and civilian space markets. Everyday uses for global positioning systems (GPS), such as farming, vehicle tracking, and trip planning, are enabled from the GPS satellites that are part of the global, real-time monitoring capability created by space-based assets.

There are two fundamental sources of **investment** – public and private funds. To secure public investment, a compelling political value to the nation as a whole must exist before the massive commitment required to develop such a robust national space enterprise can be undertaken. In other words, there must exist a clear-cut benefit to the American people equaling or exceeding the investment. With private investment however, the compelling driver is a strong and definable financial return to the investor. Rarely does Wall Street invest in highly speculative and unproven ventures, particularly on such a massive scale as is needed in this case. When Wall Street does, however, it's only after the federal government has shown the way through substantial pecuniary commitment.

With this in mind, it is imperative that the space enterprise be based upon paying both economic and quality-of-life dividends. To the nation, an enterprise based upon return to the national economy and upon the benefits it brings to the quality of life provides the political incentive necessary to justify massive investments of public dollars into technology and infrastructure development.

There are numerous markets to be realized and resources to be derived from space. Basing the space transportation enterprise on enabling these markets and resources will make the federal and state government commitment to space transportation technology and infrastructure development possible. That commitment will prompt the participation of private investment in building the next great economic engine – space commerce. By doing this, all customers of the space industry will greatly benefit – military, civil, and commercial. The military will have available the dual access it desires, immense space science and exploration will be enabled, and of course, space access companies will flourish.

The ideal vision of a robust space enterprise is one that provides quality of life to the greatest number, not just limited to the civil and military markets. To realize a resilient and flourishing commercial market, major investment into a **space transportation enterprise** is required.

Access to space is the enabling capability for a number of markets. Today, space access is time-consuming and expensive and does not have the reliability required to be considered and utilized as another mode of mass public transportation. In the case of the Space Shuttle, the expense is largely due to the standing army of workers and the time required to prepare the vehicle and payload for their mission. Currently, it takes approximately 4 months and 100,000 man-hours to process the Shuttle for launch because each subsystem must be recertified prior to each flight. Recertification is required because the current systems were designed for performance using 1970s technology and not designed for operability. All of this results in costs of over $10,000 per pound to orbit, which proves to be cost-prohibitive for the customer sectors needing the microgravity environment and global view to accomplish their missions.

Vandenberg Air Force Base

Cape Canaveral Spaceport

The reliability of current space vehicles, both Expendable Launch Vehicles (ELVs) and Reusable Launch Vehicles (RLVs), has led to some very limiting circumstances as well. Because each vehicle is considered a test vehicle and generally has a unique design requiring a specialized workforce, such vehicles are only allowed to fly from test ranges or restricted spaceports with flight termination systems ready to destroy the vehicle and its payload upon divergence from its intended flight path. Use of test ranges restricts launch sites to only a handful of facilities worldwide. In the United States, there are only four spaceports that regularly support launch activities. They are Kennedy Space Center/ Cape Canaveral Air Force Station in Florida; Vandenberg Air Force Base in California; Wallops Island in Virginia; and Kodiak Island in Alaska. These facility restrictions lead to price inflation because of reduced competition and also initiate processing bottlenecks, which therefore limits growth in the space industry.

Wallops Island

Kodiak Island

The limiting factor in expanding these crosscutting products and services is the space transportation capability. While there are significant challenges to providing this capability, all can be overcome, and there are several national-level space transportation development programs that exist today to address these challenges. These programs include the National Aerospace Initiative, NASA's Integrated Space Transportation Plan, the Crew Exploration Vehicle, the Evolved Expendable Launch Vehicle Program, and the X-Prize competition. Most share the goals of reducing the cost while increasing the reliability, safety, and accessibility of space travel. While government, industry, and academia all are exploring similar ideas related to developing a commercially and economically driven future space transportation capability, a cohesive vision for a space enterprise is lacking and will be provided upon adoption of a standardized space transportation system.

Crew Exploration Vehicle concept

Evolved Expendable Launch Vehicle

X-Prize Foundation

2.3 What enables the space enterprise?

An efficient space transportation system fueled by a robust space transportation enterprise.

For the nation to truly benefit from space, a robust space transportation enterprise must first exist offering a space transportation system that provides affordable, reliable, and safe access to and from space. Access must be available on demand in a fashion similar to other national transportation systems of rail, road, air, and sea. The space transportation system is thus both a prerequisite for and an enabler of the growth of space markets and the benefits to be secured from them.

To realize the national imperative, new space transportation capabilities must be reliable, safer, and more cost-effective. To achieve these goals, a new concept in space transportation is presented – the **space transportation enterprise** (see Figure 7). This enterprise, enabled by the **space transportation system**, effective **governance**, and adequate **investment**, furthers the achievement of national imperatives through increased access to and utilization of space.

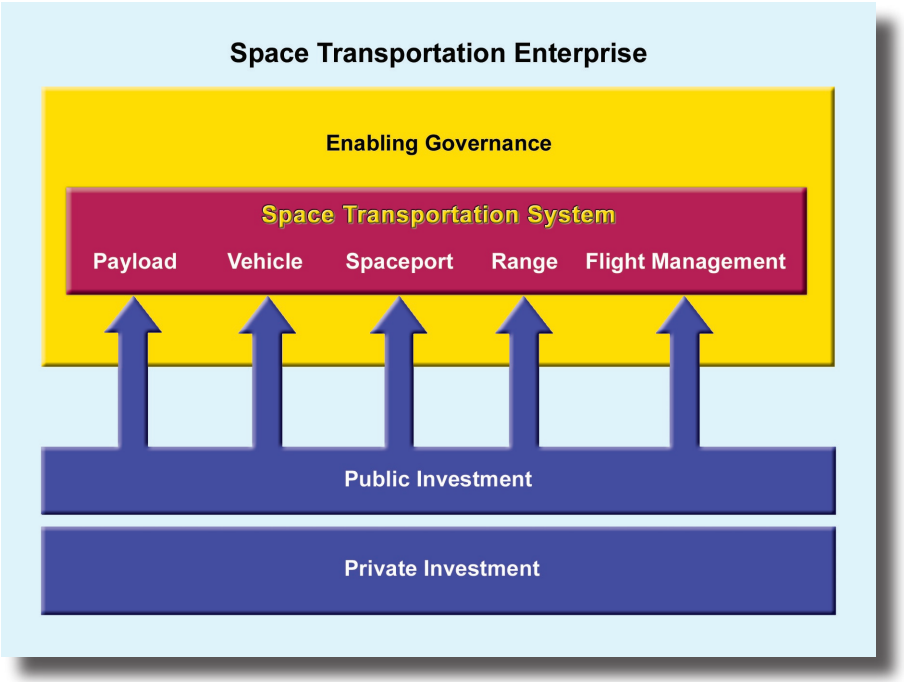


Figure 7. Space transportation enterprise

Governance

Governance provides and imposes regulatory and policy provisions at both the federal and state levels. The space transportation system operates according to these policies, regulations, and requirements. Efficient operations require enabling legislation, investment incentives, policy direction, and in some cases, regulatory relief. At the time of their establishment, it is essential that policies and regulations be extremely responsive to industry needs and foster commerce, without obstructing the progress.

Investment (Public and Private)

Public and private investment enhances the space transportation system. Investment in payload includes new capabilities for commercial (e.g., communication satellites), civil (e.g., the Hubble telescope), and military (e.g., remote sensing) uses. Vehicle investments include both private (e.g., X-Prize) and public (e.g., Orbital Space Plane) programs. Spaceports receive public investment from local, state, and national resources. Flight management investments are made in developing technology (e.g., range upgrades) and developing a space regulatory environment (e.g., the FAA).

Space Transportation System

The space transportation system has five components: **Payload**, **Vehicle**, **Spaceport**, **Range**, and **Flight Management**.

- The **Payload** component encompasses all aspects of cargo and passenger movement. It includes support subsystems, transport containers, handling and preparation, commodity servicing, and environmental control.
- The **Vehicle** component includes all aspects of the flight vehicles that move payloads from spaceports to their destinations. This includes propulsion systems, structures, power and flight controls, instrumentation, guidance systems, thermal control, communications, and software.

- The **Spaceport** component encompasses all aspects of the ground support systems associated with the space transportation system. This includes facilities and infrastructure, real estate, security, logistics, servicing, touch labor, operations management, and transportation systems interfaces with ground transport, rail, sea, and air.
- The **Range** component provides for flight corridors and public safety. This segment includes tracking, information management, access approval, airspace security, and departure/arrival control.
- The **Flight Management** component provides space traffic coordination as well as manages vehicles and payloads in space. This segment provides the architecture for in-flight communications, data analysis, and decision-making functions.

To summarize, the **space transportation system** enables the **space transportation enterprise** to function, which in turn, provides the forum for **space products** to deliver value to **customers**. From the products, the customer can achieve the **national imperative** (see Figure 8).

Since the primary requirements for enabling a space transportation enterprise are greatly lowered costs and increased reliability and safety, a national commitment to develop the technology and infrastructure necessary to enable spaceports must be established.

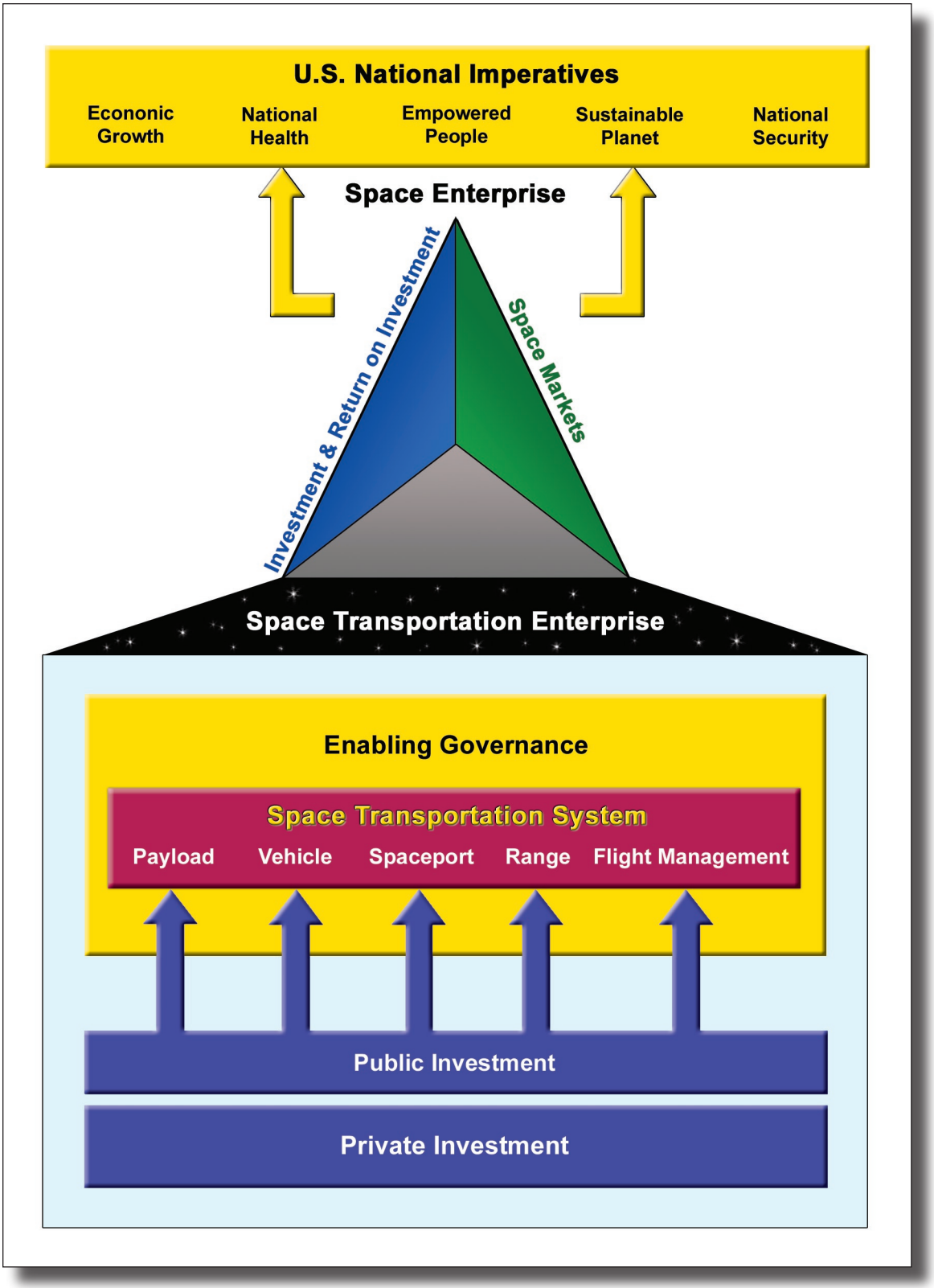


Figure 8. Flow-up of enablers to the national imperative

However, a robust space transportation enterprise must focus on cost reduction to ensure growth in the space markets. Challenging goals have been identified in hopes of making access to space affordable with the thinking that demand will drive down cost. Performance goals of reducing cost and time to access space by 50 percent and reducing the transit time between two points in space also by 50 percent have been identified, but limited success has been realized to date toward achieving those performance measures.[4]

To achieve these performance measures, a significant operational paradigm shift must occur. The overarching goal is to shift the current operational scenario to one that has efficiencies and reliability similar the aviation industry. Today in the Space Shuttle program, a significant amount of time and resources is spent processing the vehicle and payloads on the ground with little flight time (see Figure 9, left-hand pyramid). In the future, the target is to reverse that paradigm and spend minimal resources and time on the ground and a significant amount of time in flight (Figure 9, right-hand pyramid), much like the way airlines operate today. This can only be accomplished if we start designing a space transportation system from a macro- or high-level perspective and then focus on the flight vehicle specifics.

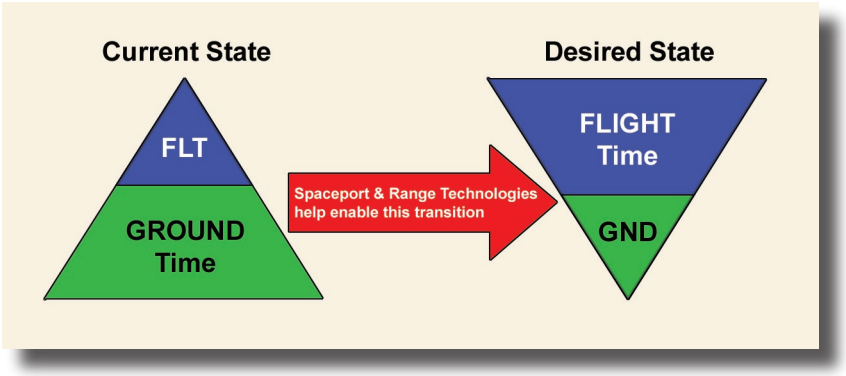


Figure 9. Operational paradigm shift

[4] R.S. Walker, *Final Report of the Commission on the Future of the United States Aerospace Industry*, November 18, 2002, <http://www.ita.doc.gov/aerospace/aerospacecommission> (October 17, 2003).

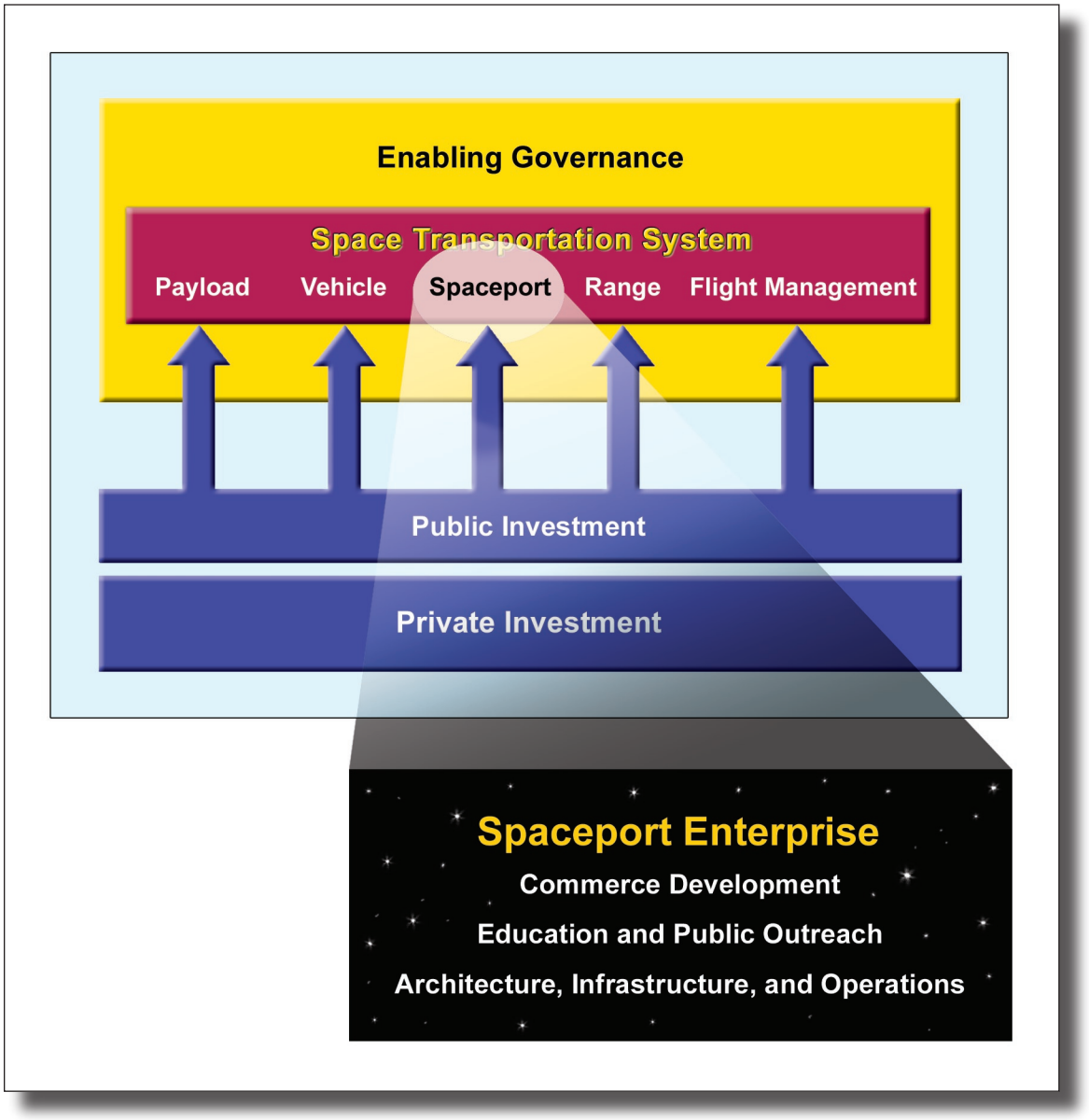


Figure 10. Key factors in the spaceport enterprise

2.4 What is a spaceport enterprise?

The spaceport enterprise consists of three key factors:

- ***Commerce Development***
- ***Education and Public Outreach***
- ***Architecture, Infrastructure, and Operations***

The **spaceport** component of the space transportation system plays an essential role in enabling the space transportation enterprise. There are three key factors (see Figure 10) that must be defined and implemented to make any space venture a success: **commerce development; education and public outreach;** and **architecture, infrastructure,** and **operations.**

Commerce Development

Spaceport commerce development is the cornerstone of the commercial spaceport enterprise. It defines the business model and establishes operating policies. The business model defines the operations, components, functions, revenues, and expenses that the business generates. A business plan describes the business model in a manner designed to attract capital investment and customers. A successful plan will attract vehicle operators, spaceport vendors, and manufacturers as users or tenants. Comprehensive spaceport plans will address point-to-point travel markets as well as limited scientific interplanetary markets and access to orbital enterprises.

Government regulation will continue to be as essential to safe spaceflight as it is today to safe airline operations. The spaceport enterprise itself will abide by rules and regulations that ensure spaceports will not only contribute to the space transportation system, but will be safe to the public and surrounding environments as well. For example, a spaceport must address environmental impacts. Environmental regulations are required to ensure that while we set out to explore the next frontier we do not destroy our current environment or the new environment in our quests. Toxins, pollutants, hazardous waste, and noise are but a few of the issues that spaceports must not only be aware of but also combat, minimizing the resulting effects on the environment. Safety to both man and nature is paramount, and therefore, regulations must be developed to ensure that everyone will be kept out of harm's way.

Education and Public Outreach

While many would enjoy seeing a new version of a spaceport built tomorrow, this is not going to happen overnight, so instead of simply dreaming about the future, it is important to educate our children and the public about what the future holds.

Public awareness is essential to the development of the thriving spaceport enterprise. Further, the public should be made aware of valuable market opportunities enabled through such an enterprise. The general public needs to know how space will benefit them, for they are the taxpayers who will fund the venture in the beginning. The general public can benefit from space even if they are not directly involved. For example, in today's model, when a launch takes place at the Kennedy Space Center, the local community is positively affected by tourism as people flock to view a launch. Hotels, stores, and restaurants, while not directly involved in the space industry, are impacted positively by the space industry.

Developing and sustaining an educated and competent workforce is likewise paramount to the spaceport enterprise. Responsibilities for developing the workforce lie in the current, near-term, and long-term workforce. The public needs to be educated on the benefits of a spaceport within their community, beginning with primary and secondary education, not only stressing the importance of math and science projects but also the idea of creativity. By educating university students, they will have the dream and drive to go into the public and private sectors and further spread awareness of the need for the space industry and spaceports. Perhaps some of these students will become the spaceports employers and operators of the future.

Architecture, Infrastructure, and Operations

The architecture will certainly vary from one spaceport to another, but at the same time, the infrastructure of all spaceports will be similar to an extent. Just as airports today attempt to individualize themselves, spaceports will most likely do the same, but many of the characteristics and services will remain similar. The purpose never changes – a spaceport is an origin or destination of a vehicle on a flight. While some spaceports will have multiple runways and launch pads, they will still operate in the same arena as any other spaceport. The spaceport architecture may include launch pads, runways, taxiways, ramps, terminals, hangars, maintenance shops, and control towers. In addition, specialized services may be offered as distinct features that an individual spaceport could market, but spaceport architectures will be similar to help standardize the operational systems for ground-based support.

Besides the architecture already mentioned, there may also be a controlling body to safely direct vehicles from spaceports to their final destinations. As exemplified by air traffic control in the aviation industry today, a similar but appropriately modified establishment could keep space vehicle operations safe. Precision guidance and approach systems will be commonplace in spaceports as in the aviation industry of today, though more advanced. In addition, other anti-incursion systems may be seen at spaceports, such as surface detection radar and onboard software that will keep vehicles separated while they taxi on the ground.

Regardless of the ultimate forms of spaceport architecture – manned or unmanned, orbital or suborbital, few or many– the space enterprise will count on spaceports to be the origin and destination of spaceflights. Spaceports will market themselves differently but rely on some common architecture and a standardized infrastructure to ensure a safe and efficient operating environment for all.

Although all elements of the space transportation system need to be addressed to achieve low-cost, routine access to space, this report will only focus on the architecture, infrastructure, and operations of the space transportation system, collectively addressed throughout this introduction as the spaceport.